Development of Monocapillary X-ray Optics for Synchrotron Applications

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Monocapillary x-ray optics are a candidate technology for producing micron and submicron beams of x-rays for a variety of microanalytical applications. At the ALS, these optics can be used to perform diffraction and fluorescence analysis of materials with submicron spatial resolution. Capillary optics are formed by re-drawing a glass tube, at high temperature, to produce a pre-selected optical figure. We have brought on-line an advanced capillary puller that is capable of drawing a wide range of figures in a reproducible fashion. We can routinely achieve a desired figure to within a slope error of 50 to 300 microradians, depending on the quality of the glass starting material.

The performance of these optics has been characterized at the ALS on the basis of their efficiency, spot size, and divergence. Early experiments used the output directly from a bending magnet on Beamlines 10.3.1 and 10.3.2. These optics typically had entrance diameters from 25 to 100 microns and exit diameters of less than 3 microns. More recent activities have explored the feasibility of advanced optical systems that rely on pre-focusing mirrors to concentrate the radiation onto the entrance of the capillary optic. We designed and tested a series of optics that take the output from the Kirpatrick-Baez (K-B) mirror pair on Beamline 10.3.2 and condense it further to produce a submicron beam of x-rays. Figure 1 shows the shape of a representative capillary optic. Typically, the tip of the optic is beveled to allow the sample to be placed very close to the exit of the capillary optic.

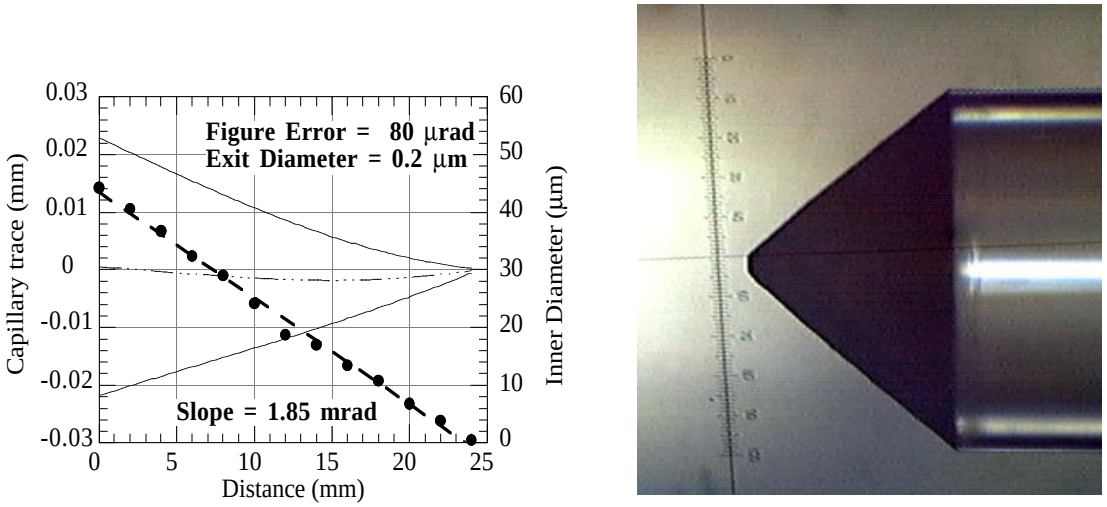

Figure 1. Internal diameter of typical optics is matched to the convergence angle of the Kirpatrick-Baez focusing mirrors on 10.3.2. The tip of the capillary optic is beveled at 45 or 60 degrees so that the capillary tip can be placed close to the sample and still allow the fluorescent or diffracted x-rays to reach a detector.

We tested these optics during two experimental series in 1998 and demonstrated that the output from the K-B mirror pair is efficiently coupled into the capillary optic. We measured the x-ray beam diameter by scanning a wire through the beam at various distances from the capillary tip. Figure 2 shows representative results obtained with the capillary optic shown in Figure 1, at a distance of about 50 μm from the exit of the capillary. The measured diameter of 0.37 μm FWHM is about a factor of four lower than the 1.4 μm diameter FWHM produced by the K-B mirror pair. Depending on the capillary design and distance from the exit of the capillary, we have measured beam diameters from 0.2 to 0.6 μm FWHM. A typical efficiency for these optics (defined by the ratio of the ion chamber signal produced by the K-B mirror pair to the signal produced by the combination of the K-B mirror pair and the capillary optic) ranges from 30 to 50%. For the capillary shown in Figure 1 we measured an efficiency of 40%. Thus, given a 50 μm stand-off distance, this capillary produced an increase in flux of 6X while reducing the beam diameter by a factor of 4. The beam divergence was measured to be about 6 mrad which currently limits the distance between sample and the capillary tip to less than about 50 μm, in order to preserve the small spot.

Future effort will be devoted to further reducing the spot-size and divergence of the x-ray beam produced by these optics. Additionally we will be conducting a series of microdiffraction and fluorescence experiments to demonstrate applications that are of interest to the semiconductor, optoelectronic, and advanced materials industries.

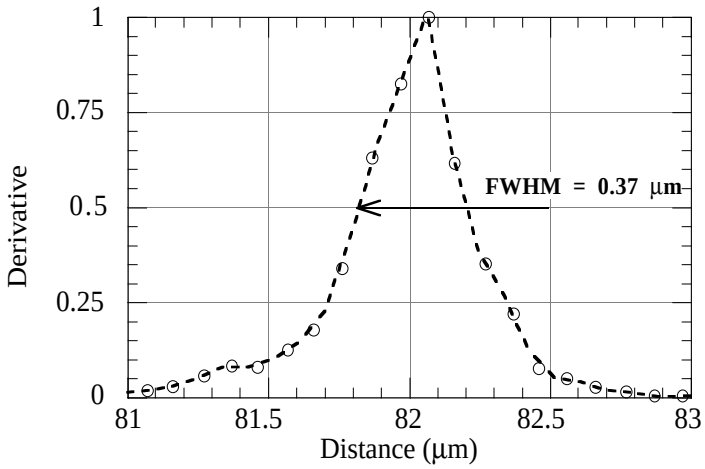

Figure 2. Beam profile measured by scanning a wire through the x-ray beam at a distance of about 50 μm from the capillary tip. This optic had an efficiency of 40% and a divergence of 6 mrad.

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